Journal of Forestry Research (2008) 19(3):215–218
DOI 10.1007/s11676-008-0040-5

RESEARCH PAPER

Correlation of eco-hydrographic benefit and height increment of *Robinia pseudoacacia* stand with climatic environmental factors in Yellow River Delta Wetland of China

GAO Peng[1], YANG Hui-ling[1], ZHANG Guang-can[1], ZHOU Ze-fu[2]

[1] *Shandong Agricultural University*, *Forestry College /the Key Laboratory of Ecological Environment*, *Taian 271018*, *Shandong, P. R. China*
[2] *Research Institute of Forestry*, *CAF*, *Beijing 100091*, *P. R. China*

Abstract: The relationship between eco-hydrographic benefit of forest vegetation and climatic environmental factors is one of the focuses in the research on environmental protection and ecosystem countermeasures in Wetland. The runoff, sediment and soil moisture rate dynamics in *Robinia pseudoacacia* plantation and its clearcut area were investigated in the natural runoff experiment plots in Yellow River Delta Wetland, Shandong Province, China. The correlation of height increment of *R. pseudoacacia* with nine climate factors such as light, water, heat, etc. was analyzed by stepwise regression analysis. The results showed that the amounts of runoff and sediment in clearcut area of *R. pseudoacacia* were 53.9%–150.8% and 172.8%–387.1% higher than that in *Robinia pseudoacacia* plantation, respectively. The runoff peak value in *R. pseudoacacia* stand was obviously lower than that in clerarcut area, meantime, the occurrence of runoff peak in *R. pseudoacacia* stand was 25 min later than in its clerarcut area. The soil moisture rates in *R. pseudoacacia* stand and its clearcut varied periodically with annual rainfall precipitation in both dry season and humid season. The annual mean soil moisture rate in *R. pseudoacacia* stand was 23.3%–25.6% higher than that in its clearcut area. Meanwhile, a regression model reflecting the correlation between the height increment of *R. pseudoacacia* and climatic factors was developed by stepwise regression procedure method. It showed that the light was the most important factor for the height increment of *R. pseudoacacia*, followed by water and heat factors.

Keywords: Yellow River Delta wetland; *Robinia pseudoacacia* stand; Eco-hydrographic benefit; height increment; climatic factors

Introduction

Robinia pseudoacacia is not only a major tree species for ecological protection forest in "three-North" areas (including North-east, North-west and North-middle areas) because of its important functions of improving ecological environment, controlling soil erosion, and adjusting river water table, but also a key tree for fuel forest (Wang et al. 2002; Feldhake 2001). The hydrographic and ecological benefits of the ecological protection forest in Loess Plateau of China and other countries have been well reported (Wang et al. 1991; Wang et al. 1994; Yu et al. 2005; Fan et al. 2006; Gi et al. 2007; Chowdhury et al. 2007), and most of those studies deal with improving soil physical properties, increasing soil infiltration, decreasing surface runoff and soil loss, etc. Zhang (2004) studied the soil hydro-physical properties of *R. pseudoacacia* plantation forestland in Loess Plateau; Han (2003) reported the soil water change of the different artificial *R. pseudoacacia* site conditions in Yan'an experimental area; Zhang (2002) regarded *R. pseudoacacia* forest as one of the experiment sites to research the dynamic change of soil water and the function of water storage. However, very few researches were conducted to measure the water storage, water and soil conservation, and the soil moisture rate dynamics in the artificial protection forest of *R. pseudoacacia* in the Yellow River Delta wetland of China. The present study was to assess quantitatively the runoff and sediment and the correlation between the height increment of *R. pseudoacacia* protection forest and climatic factors through a fixed observation in the natural runoff plots in the Yellow River Delta wetland, with a attempt to provide scientific base for regeneration, pattern arrangement and comprehensive benefits assessment of artificial protection forest of *R. pseudoacacia* of China.

Materials and methods

Study area

Yellow River Delta (YRD), which is located in economic circle of circum-Bohai Sea and Northeast Asia Economic Region, is not only the largest natural reserve area of river delta in China

Foundation project: Subsidized by the National "11th Five Year" Plan of Science and technology (2006BAD26B06, 2006BAD03A1205) and Ecological Restore Project of Water Resources Ministry of China (2006–2008).
Received: 2008-02-22; Accepted: 2008-03-08

Biography: GAO Peng (1967-), male, Ph. D., Professor in Shandong Agricultural University, Shandong Tai'an 271018, P. R. China. (Email: gaopeng@sdau.edu.cn)
Responsible editor: Zhu Hong

but also one of the most representative eco-system of river wetland in the world. YRD wetland has enormous economic potential of sustainable development because of its particular geographic position and climatic feature, and it also has enormous ecological function in purifying water resource, decomposing pollutant, supplying ground water, maintaining regional water balance, adjusting climatic, etc.

The experiment was conducted in the wetland natural reserve of YRD (37°35′–38°12′N latitude, 118°33′–119°20′E longitude) in the south of the Bohai and the west of the Laizhou bay. The experimental site belongs to the typical monsoon climate of warm temperate zone with distinct season change. The mean annual precipitation is 640 mm and nearly 70% of falling between May and September. Average annual evaporation amount is 1942.6 mm and mean annual temperature is about 13.4ºC. The mean annual wind speed is 2.98 $m\cdot s^{-1}$ and the frost-free period is 142d.

The vegetation of the YRD wetland belongs to deciduous forests in the warm temperate zone and deciduous oak forest in north warm temperate sub-zone, with a vegetation coverage rate of 53.7%, including natural vegetation and artificial vegetation. The preponderant tree species are *Fraxinus mandshurica*, *R. pseudoacacia*, *Pinus tabulae*, *Platycladus orientalis*, *Populus davidiana*, etc.. Shrub species include *Tamarix chinensis*, *Caragana microphylla*, *Lespedeza biaolorcz* and *Zizyphus jujubamill*, and so on. *R. pseudoacacia* is one of important artificial vegetations in YRD wetland. Its area amounts to 113 km^2, accounting for about 19.3% of the vegetations of YRD wetland. The soil types under vegetation change from fluvo-aquic soil to saline soil gradually, and the new soil was seriously secondary salinized.

Design of the natural runoff plots

The natural runoff plots in *R. pseudoacacia* stand and its clearcut area were designed, which had the similar conditions except vegetation coverage rate (Table 1). The forestation density of *R. pseudoacacia* was 666.7 $stems\cdot ha^{-1}$ in all the plots with an area of 100 m^2. The intercepting ditch and triangular were constructed at one end of the runoff. The design discharge of the triangular measuring weir was 0.198 $m^3\cdot s^{-1}$.

Table 1. Conditions of the natural runoff plots of *Robinia pseudoacacia* and its clearcut area

Sample plots	Site type	Age (year)	Stem diameter at breast height (cm)	Total height (m)	Coverage (%)	Slope (°)
01	Stand	7	16.1	16.5	87.1	26.2
02	Stand	8	18.6	18.1	90.2	245
03	Stand	9	19.7	19.3	85.8	25.7
04	Stand	9	19.2	18.7	94.1	24.7
05	Stand	8	17.9	17.5	87.9	27.8
06	Stand	7	16.8	17.2	89.0	26.9
07	Stand	8	18.4	17.7	92.7	24.8
08	Stand	7	15.8	16.2	85.6	24.1
09	Stand	8	17.2	16.6	87.1	25.9
10	Stand	9	18.5	17.3	93.4	25.1
11*	Clearcut	2	——	——	30.2	25.2
12*	Clearcut	2	——	——	32.4	26.1

Notes: *----Clearcut area of *Robinia pseudoacacia* for two years. Shrub and herbage are *Caragana microphylla* and *Setaria lutescens*, with coverage of 30.2% and 32.4%, respectively.

Measurement of runoff, sediment and soil moisture rate

The amount of runoff was measured using the sediment pool, automatic water-stage recorder and triangular measuring weir. The amount of sediment was the sum of the dry weight of suspended load and the dry weight of tractional load. The dry weight of suspended load was the sand being filtrated from the runoff sample, and the dry weight of tractional load was the sand depositing in sediment pool. By choosing three spots, such as upside, middle and below slope part, the soil moisture rates were measured at the soil layer of 0–10 cm, 10–20 cm and 20–30 cm on 1st, 11th and 21st day each month. The soil moisture rate was measured with the oven dry method.

Increment determination of *Robinia pseudoacacia*

With the typical sampling method, 10 sample plots were set in the standard area of *R. pseudoacacia* protection forest. Stem diameter at breast height and total height were recorded for each tree in each plot (Table 1). The trees for decomposition analysis were selected according to mean diameter and mean height. Only one tree was selected for decomposition analysis in each sample plot. The tree was cut at 0.0, 1.3, 3.6, 5.6 and 7.6 m for dials. The diameter current annual increment and annual zone numbers of the tree dials were recorded, and then the mean height increment (MHI) was calculated by the section height and the annual zone numbers between the two sections (Table 3).

Climatic factors

Climatic data were provided by Climate Bureau of Dongying City of Shandong Province and the time range of the data that was in accordance with the data of the annual increment of the forest (1999–2006). According to the biological and ecological characters of *R. pseudoacacia*, climatic factors selected include annual sunshine hours (SH, X_1), annual mean temperature (MT, X_2), annual highest temperature (HT, X_3), annual ≥10˚C accumulated temperature (AT10, X_4), annual ≥0˚C accumulated temperature (AT0, X_5), annual precipitation (AP, X_6), annual moisture index (AMI, X_7), annual relative humidity (RH, X_8), annual evaporation (AE, X_9). Moreover, A_{M} could be calculated by the following equation:

$$A_{\mathrm{MI}} = R / 0.16 \sum t \tag{1}$$

where, R is the precipitation amount for every day annual air temperature ≥10 ºC, and Σt is the accumulated temperature for every day annual air temperature ≥10 ºC).

Statistical analysis methods

The statistical analyses were conducted by using SPSS-PC statistical software (Lu 2002) and Excel statistical software (Wang 2003). Stepwise regression analysis was performed to find out main climatic factor*s* affecting the height increment of *R. pseudoacacia*.

Results

Runoff and sediment

A significant difference in runoff and sediment was found between *R. pseudoacacia* stand and its clearcut area (Table 2). Compared to *R. pseudoacacia* stand, the amount of runoff in clearcut area increased by at least 53.9% and as high as 150.8% (F=18.156>$F_{0.01}$=7.59), and the amount of sediment in clearcut area increased by 172.8%–387.1% (F=23.156>$F_{0.01}$=7.59). The results revealed that *R. pseudoacacia* stand could decrease surface runoff, increase infiltration of rainfall and decrease soil erosion, which is agreed with the results of Closset et al. (2006) and Hristo et al. (2005). Moreover, the hydrograph of surface runoff of typical rainfall showed that the peak value of runoff in *R. pseudoacacia* stand was 0.8 $L \cdot s^{-1}$ lower than that in its clearcut area (Fig. 1), indicating that the stand could decrease the peak value and the amount of runoff, and the occurrence of runoff peak in *R. pseudoacacia* stand lags behind for 25 min, compared to clearcut area, indicating that *R. pseudoacacia* stand could store water and delay the occurring time of flood peak.

Table 2. The amount of runoff and sediment in *Robinia pseudoacacia* stand and its clearcut area

Plot	Rainfall amount (mm)	Rainfall intensity ($mm \cdot min^{-1}$)	Amount of runoff			Amount of sediment		
			Stand (mm)	Clearcut area (mm)	Increase (%)	Stand ($t \cdot km^{-2}$)	Clearcut area ($t \cdot km^{-2}$)	Increase (%)
N_{01}	58.3	0.51	8.102	14.201	75.3	32.04	156.08	387.1
N_{02}	36.4	0.25	4.083	6.285	53.9	29.48	81.02	174.8
N_{03}	37.1	0.95	5.302	11.765	121.9	16.41	65.67	300.2
N_{04}	21.3	0.27	2.671	4.432	65.9	14.92	40.70	172.8
N_{05}	45.8	0.72	6.414	13.745	114.3	22.13	105.34	376.0
N_{06}	42.5	0.86	5.896	14.785	150.8	23.87	109.12	357.1

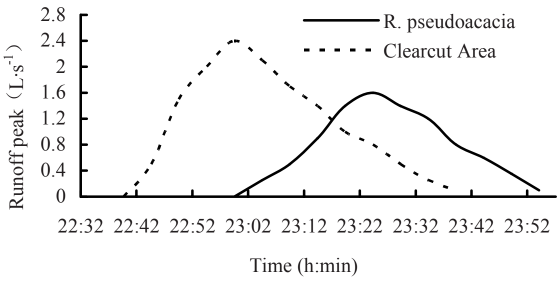

Fig. 1 Hydrograph of surface runoff of typical rainfall (N_{03}) in *Robinia pseudoacacia* stand and in its clearcut area in 2006

Soil moisture dynamics

The mean soil moisture rates in *R. pseudoacacia* stand and its clearcut area were significantly different (F=7.823 > $F_{0.01}$=7.591) (Fig. 2). The soil moisture rate in *R. pseudoacacia* stand was 23.3%–25.6% higher than in its clearcut area. The soil moisture rate in the down part, middle part and the up part of the hillslope in *R. pseudoacacia* stand was 19.3%, 25.0% and 27.4% higher than in its clearcut, respectively. The highest soil moisture rate was found in the down part of the hillslope in *R. pseudoacacia* stand. In rainy season (July–September), the soil moisture rate in *R. pseudoacacia* stand was 24.3%–29.8% higher than in its clearcut area (Fig. 2). These results demonstrate that *R. pseudoacacia* stand could intercept and reallocate the rainfall runoff and increase the soil moisture rate. As was shown in Fig. 2, the soil moisture rates in *R. pseudoacacia* stand and its clearcut area varied periodically with annual rainfall amount in dry season and humid season, i.e., the soil moisture rate was lower between the end of April to the end of June, began to increase from the early of April to mid-September, and declined from the end of September during the plant growth season.

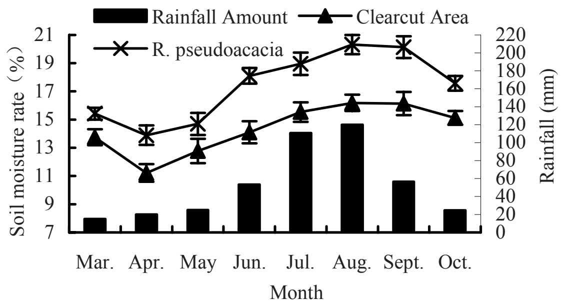

Fig. 2 Dynamic change of soil moisture rate and rainfall amount in *Robinia pseudoacacia* stand and in its clearcut area during the plant growth season in 2006

Height increment of *R. pseudoacacia*

The original data (Table 3) of the height increment of *R. pseudoacacia* and climatic factors were analyzed by stepwise regression of software, and the following regression model was obtained:

$$Y=0.87497+0.20106X_2+0.00493X_6+0.25581X_8-0.01145X_9+0.00514X_1+5.49189X_7 \quad (2)$$

where, Y is the height increment of *R. pseudoacacia,* X_2 the annual mean temperature, X_6 the annual precipitation, X_8 the annual relative humidity, X_9 the annual evaporation, X_1 the annual sunshine hours, and X_7 is the annual moisture index.

Multiple correlation coefficient: R=0.9016; Standard regression coefficient: r_2=0.9082; r_6=0.8055; r_8=0.9034; r_9=-0.9507; r_1=0.9158; r_7=0.9587

Significance test: F=7.34745>$F_{0.05}$ (6.8) =3.58. So the regression is significant.

The height increment of *R. pseudoacacia* has a closer relationship with light factor (annual sunshine hours), water factors (annual precipitation, annual evaporation, annual relative humidity), heat factor (annual mean temperature), and water and heat comprehensive factor (annual moisture index). It is also shown from the standard regression coefficient and introduced factors that the height increment is positively correlated to sunshine hours, annual precipitation, annual mean temperature, and annual wetness, and negatively correlated to annual evaporation, indicating that the light, water and heat are the three main factors affecting the height increment of *R. pseudoacacia*.

Table 3. Original data of the height increment of *Robinia pseudoacacia* and climatic factors

Time sequence	Mean height increment (cm)	Annual sunshine hours (h)	Annual mean temperature (ºC)	Annual highest temperature (ºC)	Annual ≥10˚C accumulated temperature (ºC)	Annual ≥0 ºC accumulated temperature (ºC)	Annual precipitation (mm)	Annual moisture index	Annual relative humidity (%)	Annual evaporation (mm)
1999	95.5	2687.5	11.8	39.4	4596.3	5081.3	621.7	0.85	60	1744.4
2000	166.6	2883.4	12.9	40.7	4801.3	5213.2	787.1	1.02	68	1996.2
2001	162.1	2815.8	12.3	40.2	4792.4	5205.6	766.5	1.00	63	1885.1
2002	143.2	2779.1	11.4	39.3	4721.2	5172.1	710.4	0.94	62	1802.3
2003	139.5	2735.2	12.1	38.7	4716.5	5120.3	668.8	0.89	59	1795.2
2004	120.3	2705.7	12.0	39.6	4685.2	5103.7	630.3	0.84	62	1825.4
2005	85.7	2610.1	11.5	39.1	4672.1	5013.4	751.6	1.01	61	1768.3
2006	80.6	2573.7	11.3	40.2	4581.6	5075.6	664.1	0.91	64	1783.4

Conclusions

With the positional observation, our study results showed that *R. pseudoacacia* stand could decrease surface runoff and soil erosion, and increase infiltration of rainfall. Meanwhile, *R. pseudoacacia* stand could decrease the peak value and the amount of runoff, store water and delay the occurrence time of flood peak in the YRD wetland of China. The amounts of runoff and sediment in clearcut area were increased separately by 53.9%–150.8% and 172.8%–387.1%, compared to those in *R. pseudoacacia* stand. .

Soil moisture analysis showed that *R. pseudoacacia* stand could intercept and reallocate rainfall runoff, and increase soil moisture rate. The soil moisture rates in *R. pseudoacacia* stand and its clearcut area varied periodically with annual rainfall precipitation in dry season and humid season. During the growing season, the soil moisture rate had an obvious increase from the early of July to mid-September and began to decline from the end of September. The annual mean soil moisture rate in *R. pseudoacacia* stand was higher than in its clearcut area, and in the rainy season the soil moisture rate in *R. pseudoacacia* stand was 24.3%–29.8% higher than in its clearcut area (Fig. 2).

The changes of climatic factors had some effects on the height increment of *R. pseudoacacia* protection forest in YRD Wetland of China. Multiple stepwise regression analysis showed that the light was the most important factor for the height increment of *R. pseudoacacia*, followed by water and heat factors. Therefore, adjusting the plant-spacing and row-spacing and controlling the rational density of plantation must be good measures for development of *R. pseudoacacia* protection forest in YRD wetland of China. Through these management measures of controlling light factor, the sunshine hours and sunshine areas can be increased for the good growth conditions of *R. pseudoacacia* protection forest. More attention should be paid to the effects of water conditions on the growth of *R. pseudoacacia* in the intensive management and the cultivation.

According to the study, it is concluded that the artificial protection forest of *R. pseudoacacia* play an important role in soil and water conservation in the YRD wetland. Therefore, we should speed up establishing *R. pseudoacacia* plantation as artificial protection forest in the YRD wetland of China. Moreover, because of *R. pseudoacacia* being also a key tree for fuel forest, we should pay more attention to its cutting style, cutting cycle, and regeneration after removal of old growth.

References

Closset KD, Schnitzler A, Aran D. 2006. Dynamics in natural mixed-beech forest of the Upper Vosges. *Biodiversity and Conservation*, **15**(3): 1063−1093.

Fan A'na, Chen Xiangwei, Li Zhimin. 2006. Effects of intercropping systems of trees with soybean on soil physicochemical properties in juvenile plantations. *Journal of Forestry Research*, **17**(3): 226−230.

Feldhake CM. 2001. Microclimate of a natural pasture under planted *Robinia pseudoacacia* in central Appalachia, West Virginia. *Agroforestry Systems*, **53**(5): 297−303.

Gi JK, Bo AL, Jong MN, Jae GK. 2007. The relationship of vegetation to environmental factors in Wangsuk stream and Gwarim reservoir in Korea: II. Soil environments. *Ecol Res*., **22**(6):75−86.

Han Ruilian, Hou Qingchun. 2003. Soil water changing of artificial *Robinia persudoscacia* at different site conditions in Yan'an experimental area. *Journal of Northwest Forestry University*, **18**(1):74−76. (in Chinese).

Hristo T, Alexander A. 2005. Growth of *Robinia persudoscacia* L. on are-claimed terrain in Bulgaria studied over a period of climatic anomalies. *ProQuest Agriculture Journals*, **32**(1): 1−5.

Lu Wendai. 2002. SPSS10.0 for windows statistics analysis. Beijing: Electron Industry Press, 1−135. (in Chinese).

Chowdhury MSH, Halim MA, Biswas S. 2007. Comparative evaluation of physical properties in soils of orange orchard and bushy forest in chittagong hill tracts, Banglandesh. *Journal of Forestry Research*, **18**(3): 245−248.

Wang Keqin, Wang Binrui. 2002. Study on thinning to *Robina pseudoacacia* forest on the Loess Plateau. *Chinese Journal of Applied Ecology*, **13**(1): 11−15. (in Chinese).

Wang Wenzhong. 2003. The application of Excel in statistics. Beijing: Chinese Railway Press, 1−67. (in Chinese).

Wang Yukuan, Wang Zhanli. 1991. Study on the Runoff Generation Process on hillside fields on the Loess Plateau. *Journal of Soil and Water Conservation*, **2**(2): 35−40. (in Chinese).

Wang Youmin, Liu Bingzheng. 1994. *Ecological characteristics of Shelter Forest on the Loess Plateau*. Beijing: Chinese Forestry Publishing House, 105−132. (in Chinese).

Yu Dapao, Gu huiyan, Wang Jiandong. 2005. Relationships of climate change and tree ring of Betula ermanii tree line forest in Changbai Mountain. *Journal of Forestry Research*, **16**(3): 187−192. (in Chinese).

Zhang Jianjun, Zhang Baoying, Bi Huaxing. 2002. Soil erosion resistance of different land types in Loess Plateau area. *Journal of Beijing Forestry University*, **26**(6): 25−29. (in Chinese).

Zhang Sheqi, Wang Guodong. 2004. Soil hydro-physical properties of *Robinia pseudoacacia* plantation forestland in Loess Plateau. *Journal of Northwest Forestry University*, **19**(3): 11−14. (in Chinese).